

Force Concept Inventory

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The *Force Concept Inventory* (FCI) is a multiple-choice "test" designed to assess student understanding of the *most basic* concepts in Newtonian mechanics. The FCI can be used for several different purposes, but the most important one is to evaluate the effectiveness of instruction. For a full understanding of what has gone into the development of this instrument and how it can be used, the FCI papers^{1,2} should be consulted, as well as: (a) the papers on the Mechanics Diagnostic Test^{3,4}, the FCI predecessor, (b) the paper on the Mechanics Baseline Test⁵ which is recommended as an FCI companion test for assessing quantitative problem-solving skills, and (c) Richard Hake's⁶ data collection on university and high school physics taught by many different teachers and methods across the USA.

References

1. David Hestenes, Malcolm Wells, & Gregg Swackhamer (1992). Force Concept Inventory, *The Physics Teacher*, **30** (3), 141-151.
2. David Hestenes & Ibrahim Halloun (1995). Interpreting the Force Concept Inventory, *The Physics Teacher*, **33** (8), 502, 504-506.
3. Ibrahim Halloun & David Hestenes (1985). The initial knowledge state of college physics students, *American Journal of Physics*, **53** (11), 1043-1055.
4. Ibrahim Halloun & David Hestenes (1985). Common sense concepts about motion, *American Journal of Physics*, **53** (11), 1056-1065.
5. David Hestens & Malcolm Wells (1992). A Mechanics Baseline Test, *The Physics Teacher*, **30** (3), 159-166.
6. Richard Hake (1994, August). Survey of Test Data for Introductory Mechanics Courses, *AAPT Announcer*, **24** (2), 55.

Force Concept Inventory

Please:

*Do **not** write anything on this questionnaire.*

Mark your answers on the ParSCORE computer sheet.

*Make **only one** mark per item.*

*Do **not** skip any question.*

*Avoid guessing. Your answers should reflect what **you** personally think.*

On the ParSCORE computer sheet:

*Use a **No. 2 pencil** only, and follow marking instructions.*

Fill in your ID number. This is the number given to you by your school or your teacher.

*Mark “**A**” under “Test Form”.*

Fill in the “Exam No.” given by your teacher.

Plan to finish this questionnaire in 30 minutes.

Thank you for your cooperation.

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
 - (A) about half as long for the heavier ball as for the lighter one.
 - (B) about half as long for the lighter ball as for the heavier one.
 - (C) about the same for both balls.
 - (D) considerably less for the heavier ball, but not necessarily half as long.
 - (E) considerably less for the lighter ball, but not necessarily half as long.

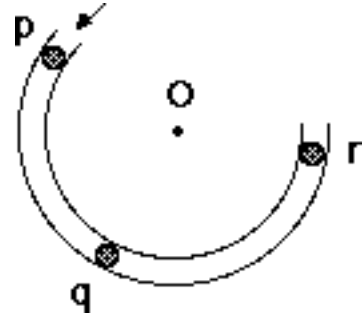
2. The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:
 - (A) both balls hit the floor at approximately the same horizontal distance from the base of the table.
 - (B) the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
 - (C) the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
 - (D) the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
 - (E) the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

3. A stone dropped from the roof of a single story building to the surface of the earth:
 - (A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
 - (B) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
 - (C) speeds up because of an almost constant force of gravity acting upon it.
 - (D) falls because of the natural tendency of all objects to rest on the surface of the earth.
 - (E) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

4. A large truck collides head-on with a small compact car. During the collision:
 - (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
 - (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
 - (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
 - (D) the truck exerts a force on the car but the car does not exert a force on the truck.
 - (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r."

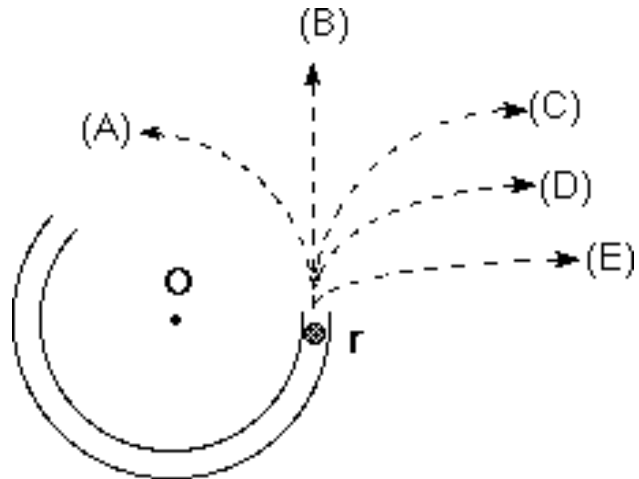


5. Consider the following distinct forces:
1. A downward force of gravity.
 2. A force exerted by the channel pointing from q to O.
 3. A force in the direction of motion.
 4. A force pointing from O to q.

Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?

- (A) 1 only.
 (B) 1 and 2.
 (C) 1 and 3.
 (D) 1, 2, and 3.
 (E) 1, 3, and 4.

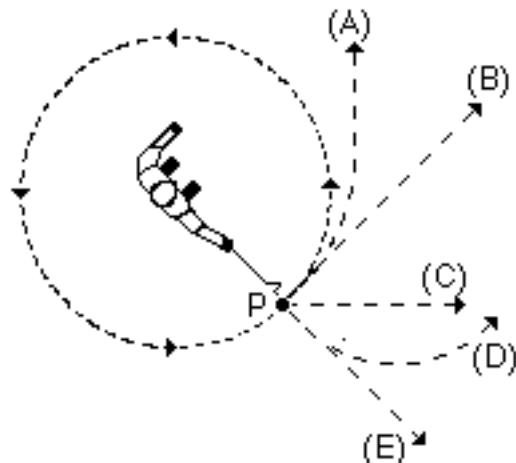
6. Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?



7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure.

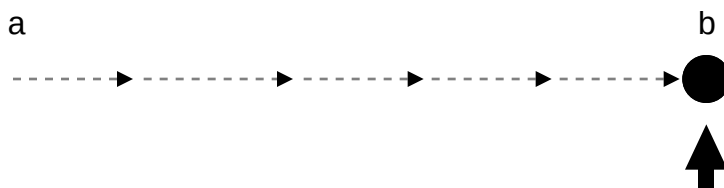
At the point P indicated in the figure, the string suddenly breaks near the ball.

If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

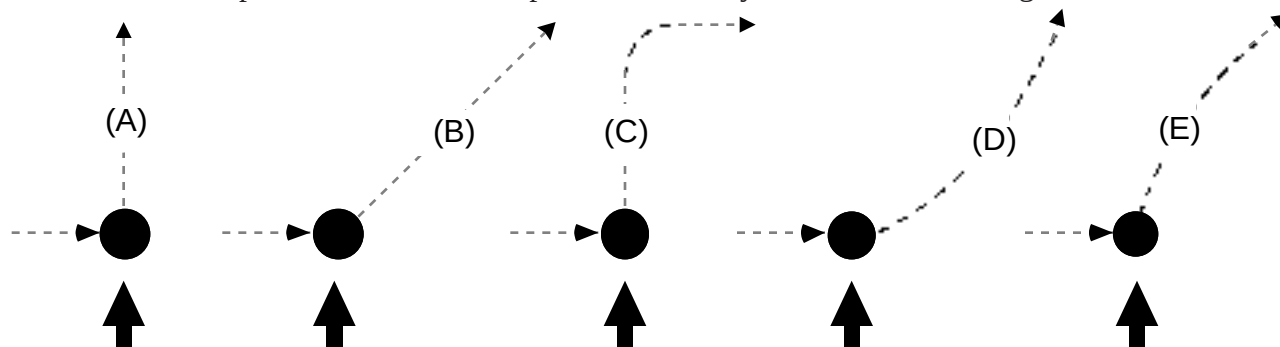


USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).

The figure depicts a hockey puck sliding with constant speed v_0 in a straight line from point "a" to point "b" on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point "b," it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b," then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick.

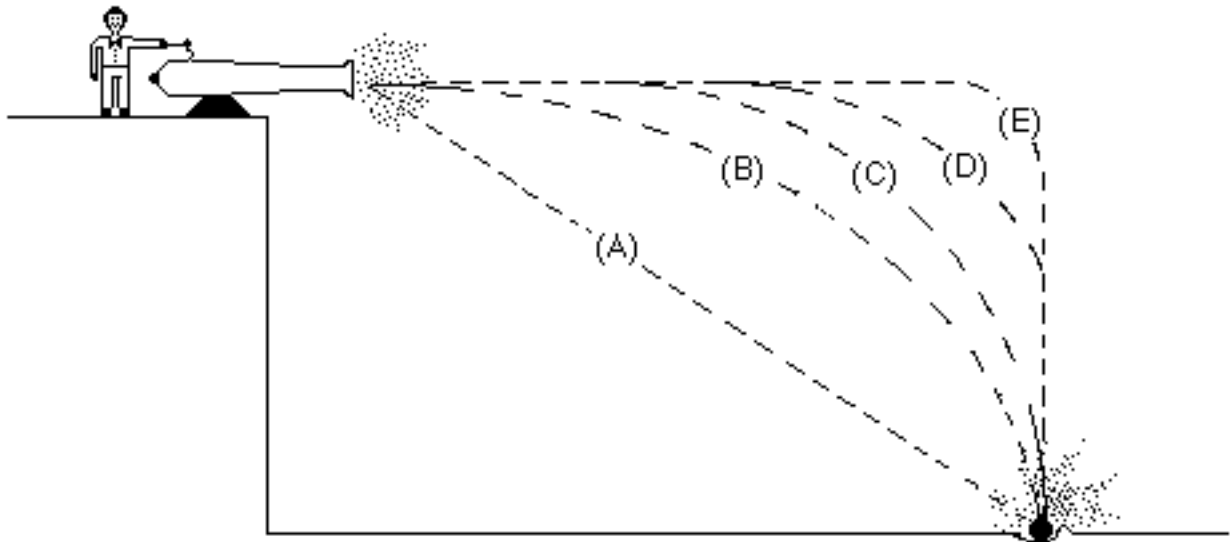


8. Which of the paths below would the puck most closely follow after receiving the kick?



9. The speed of the puck just after it receives the kick is:
- (A) equal to the speed " v_0 " it had before it received the kick.
 - (B) equal to the speed " v_k " resulting from the kick and independent of the speed " v_0 ".
 - (C) equal to the arithmetic sum of the speeds " v_0 " and " v_k ".
 - (D) smaller than either of the speeds " v_0 " or " v_k ".
 - (E) greater than either of the speeds " v_0 " or " v_k ", but less than the arithmetic sum of these two speeds.
10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:
- (A) is constant.
 - (B) continuously increases.
 - (C) continuously decreases.
 - (D) increases for a while and decreases thereafter.
 - (E) is constant for a while and decreases thereafter.
11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are):
- (A) a downward force of gravity.
 - (B) a downward force of gravity, and a horizontal force in the direction of motion.
 - (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
 - (D) a downward force of gravity and an upward force exerted by the surface.
 - (E) none. (No forces act on the puck.)

12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?

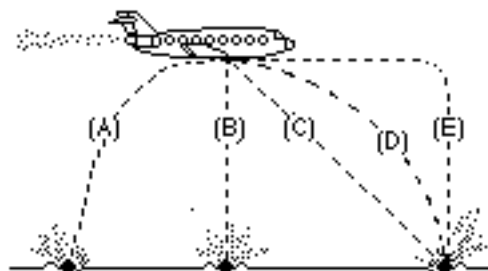


13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

- (A) a downward force of gravity along with a steadily decreasing upward force.
- (B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.
- (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.
- (D) an almost constant downward force of gravity only.
- (E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction.

As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



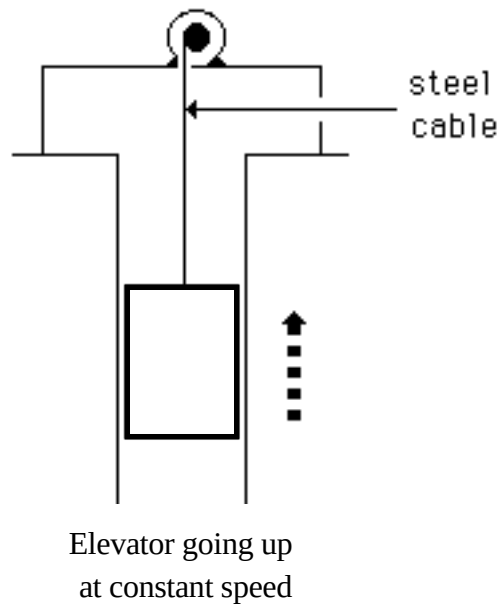
USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.



15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
 - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
 - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
 - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
 - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.
16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
 - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
 - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
 - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
 - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:
- (A) the upward force by the cable is greater than the downward force of gravity.
 - (B) the upward force by the cable is equal to the downward force of gravity.
 - (C) the upward force by the cable is smaller than the downward force of gravity.
 - (D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
 - (E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).

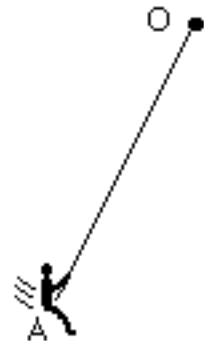


18. The figure below shows a boy swinging on a rope, starting at a point higher than A. Consider the following distinct forces:

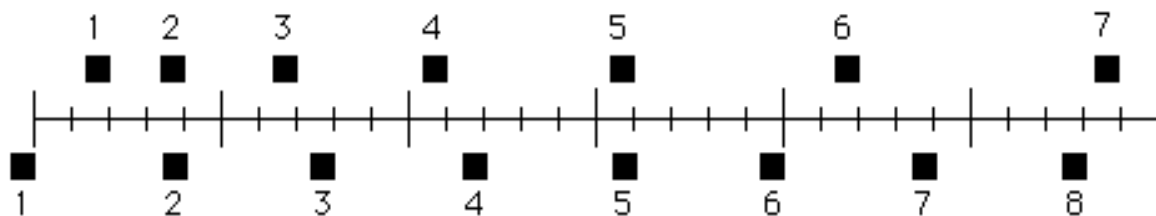
- 1. A downward force of gravity.
- 2. A force exerted by the rope pointing from A to O.
- 3. A force in the direction of the boy's motion.
- 4. A force pointing from O to A.

Which of the above forces is (are) acting on the boy when he is at position A?

- (A) 1 only.
- (B) 1 and 2.
- (C) 1 and 3.
- (D) 1, 2, and 3.
- (E) 1, 3, and 4.

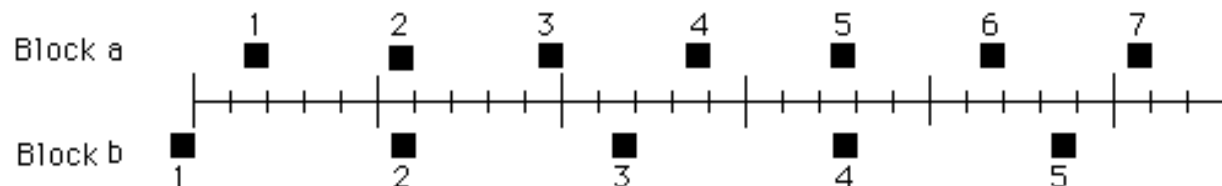


19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

- (A) No.
 (B) Yes, at instant 2.
 (C) Yes, at instant 5.
 (D) Yes, at instants 2 and 5.
 (E) Yes, at some time during the interval 3 to 4.
20. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.

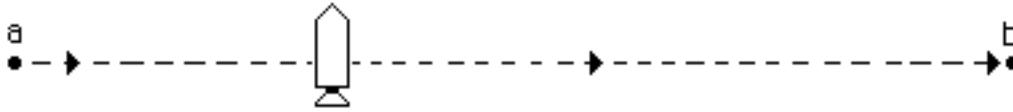


The accelerations of the blocks are related as follows:

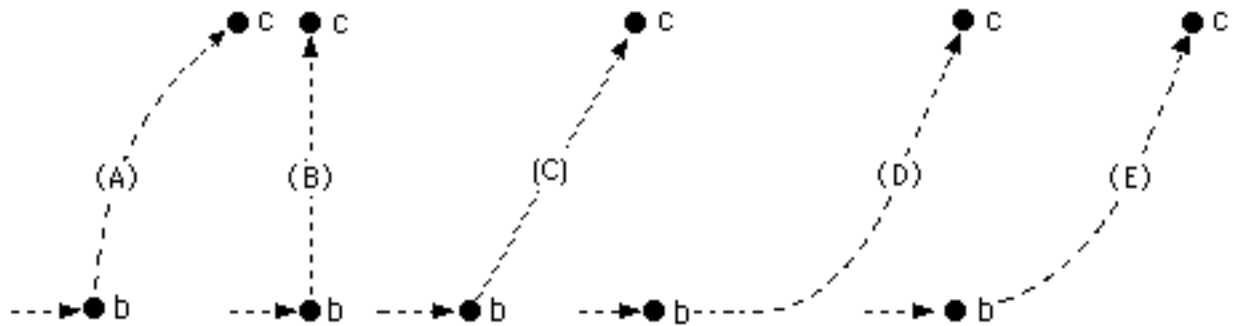
- (A) The acceleration of "a" is greater than the acceleration of "b".
 (B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.
 (C) The acceleration of "b" is greater than the acceleration of "a".
 (D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.
 (E) Not enough information is given to answer the question.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 through 24).

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.



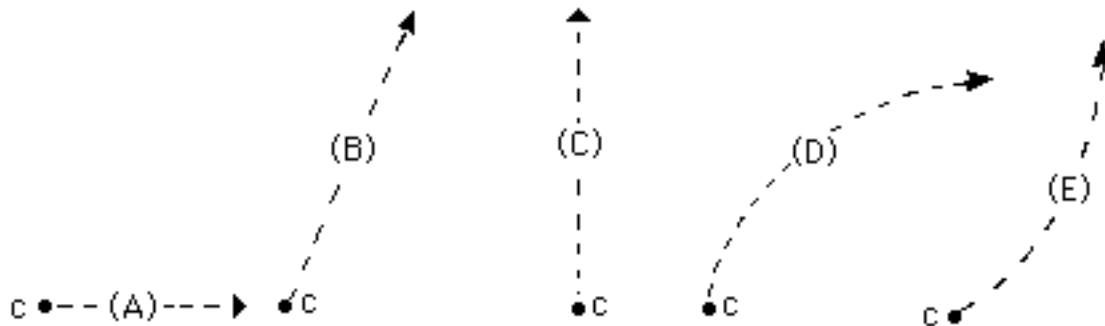
21. Which of the paths below best represents the path of the rocket between points "b" and "c"?



22. As the rocket moves from position "b" to position "c" its speed is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

23. At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?



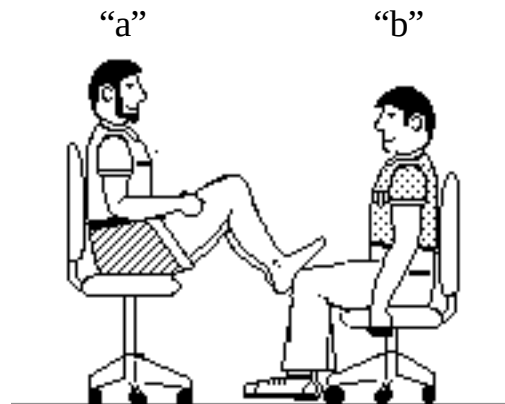
24. Beyond position "c" the speed of the rocket is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed " v_0 ".
The constant horizontal force applied by the woman:
- (A) has the same magnitude as the weight of the box.
 - (B) is greater than the weight of the box.
 - (C) has the same magnitude as the total force which resists the motion of the box.
 - (D) is greater than the total force which resists the motion of the box.
 - (E) is greater than either the weight of the box or the total force which resists its motion.
26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
- (A) with a constant speed that is double the speed " v_0 " in the previous question.
 - (B) with a constant speed that is greater than the speed " v_0 " in the previous question, but not necessarily twice as great.
 - (C) for a while with a speed that is constant and greater than the speed " v_0 " in the previous question, then with a speed that increases thereafter.
 - (D) for a while with an increasing speed, then with a constant speed thereafter.
 - (E) with a continuously increasing speed.
27. If the woman in question 25 suddenly stops applying a horizontal force to the box, then the box will:
- (A) immediately come to a stop.
 - (B) continue moving at a constant speed for a while and then slow to a stop.
 - (C) immediately start slowing to a stop.
 - (D) continue at a constant speed.
 - (E) increase its speed for a while and then start slowing to a stop.

28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other.

Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.



During the push and while the students are still touching one another:

- (A) neither student exerts a force on the other.
 - (B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
 - (C) each student exerts a force on the other, but "b" exerts the larger force.
 - (D) each student exerts a force on the other, but "a" exerts the larger force.
 - (E) each student exerts the same amount of force on the other.
29. An empty office chair is at rest on a floor. Consider the following forces:
- 1. A downward force of gravity.
 - 2. An upward force exerted by the floor.
 - 3. A net downward force exerted by the air.
- Which of the forces is (are) acting on the office chair?
- (A) 1 only.
 - (B) 1 and 2.
 - (C) 2 and 3.
 - (D) 1, 2, and 3.
 - (E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)
30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.
- Consider the following forces:
- 1. A downward force of gravity.
 - 2. A force by the "hit".
 - 3. A force exerted by the air.
- Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?
- (A) 1 only.
 - (B) 1 and 2.
 - (C) 1 and 3.
 - (D) 2 and 3.
 - (E) 1, 2, and 3.